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Kubozono

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(54) **SCALE AND ENCODER**

(56) **References Cited**

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(52) **U.S. Cl.**
CPC **G01D 5/20** (2013.01)

(58) **Field of Classification Search**
CPC G01D 5/20; G01D 5/204; G01D 5/12
See application file for complete search history.

U.S. PATENT DOCUMENTS

5,815,091	A *	9/1998	Dames	.....	G01D 5/206 340/870.34
6,124,708	A *	9/2000	Dames	.....	G01D 5/2053 324/207.12
6,249,234	B1 *	6/2001	Ely	.....	G01D 5/208 341/20
6,522,128	B1 *	2/2003	Ely	.....	G01B 7/30 324/207.17
8,421,446	B2 *	4/2013	Straubinger	.....	G01D 5/2225 324/207.15
10,564,009	B2 *	2/2020	Hubrich	.....	G01D 5/2073
2012/0223724	A1 *	9/2012	Vasiloiu	.....	G01B 7/003 324/654
2015/0219475	A1 *	8/2015	Tsuji	.....	G01D 5/24438 33/708
2016/0169717	A1 *	6/2016	Zhitomirsky	.....	G01D 5/20 702/94

FOREIGN PATENT DOCUMENTS

JP	2009-168701	7/2009
JP	5224830	7/2013
JP	2019-117322	7/2019

* cited by examiner

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LLP

(57) **ABSTRACT**

A scale includes a plurality of conductors that are arrayed in a given interval along a measurement axis, wherein each of the plurality of conductors has projection portions, each of which projects toward each side of the measurement axis, and wherein at least a part of each of the projection portions has a curve projecting in the measurement axis.

9 Claims, 6 Drawing Sheets

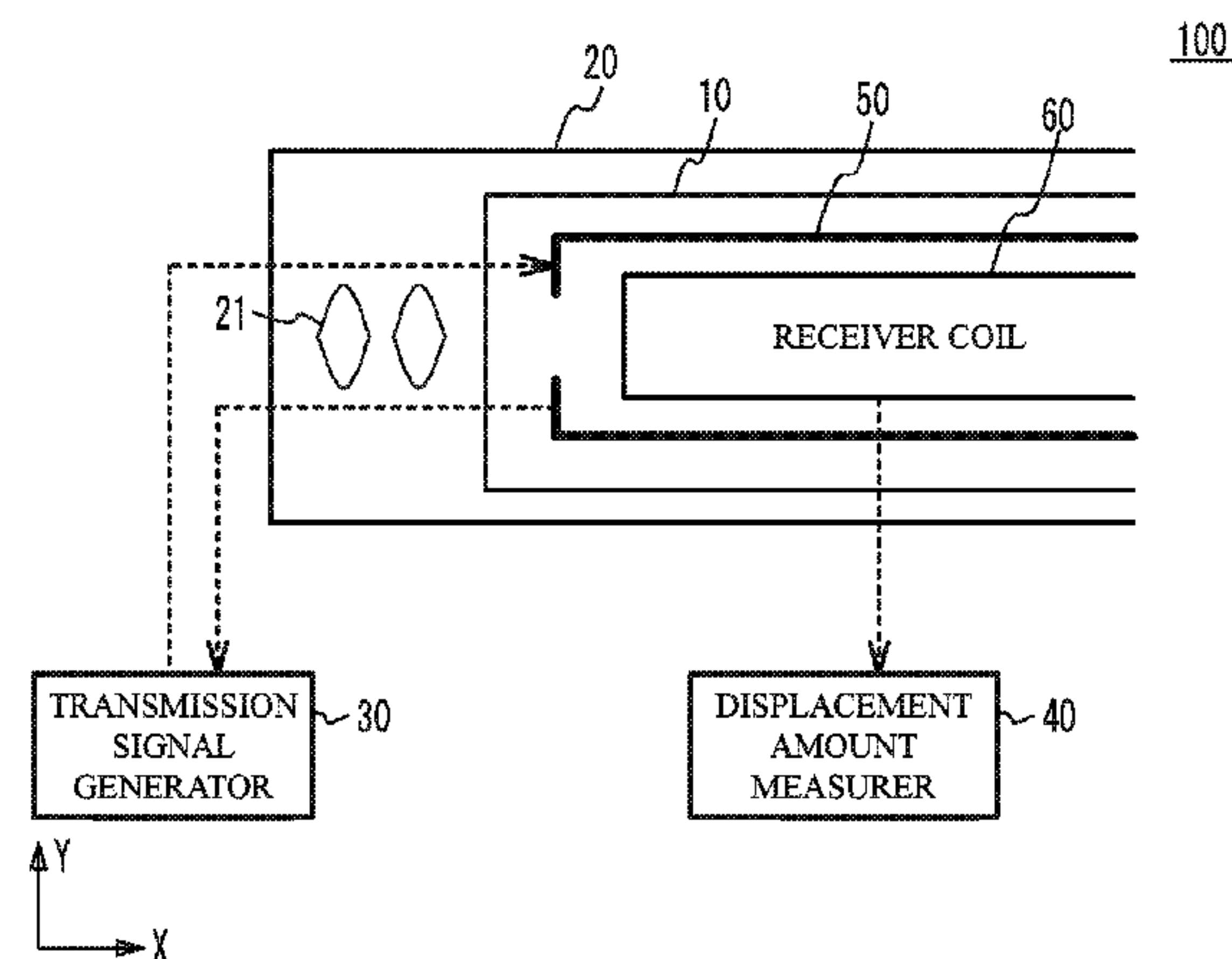


FIG. 1B

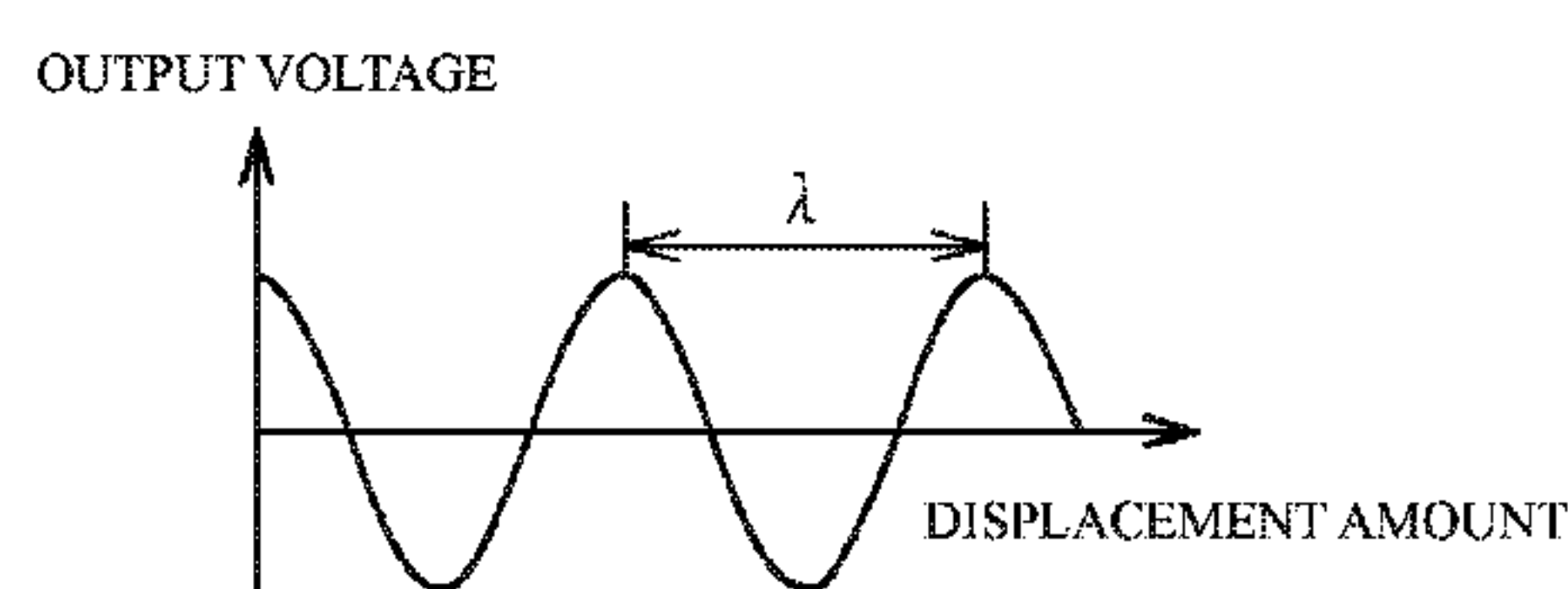


FIG. 1A

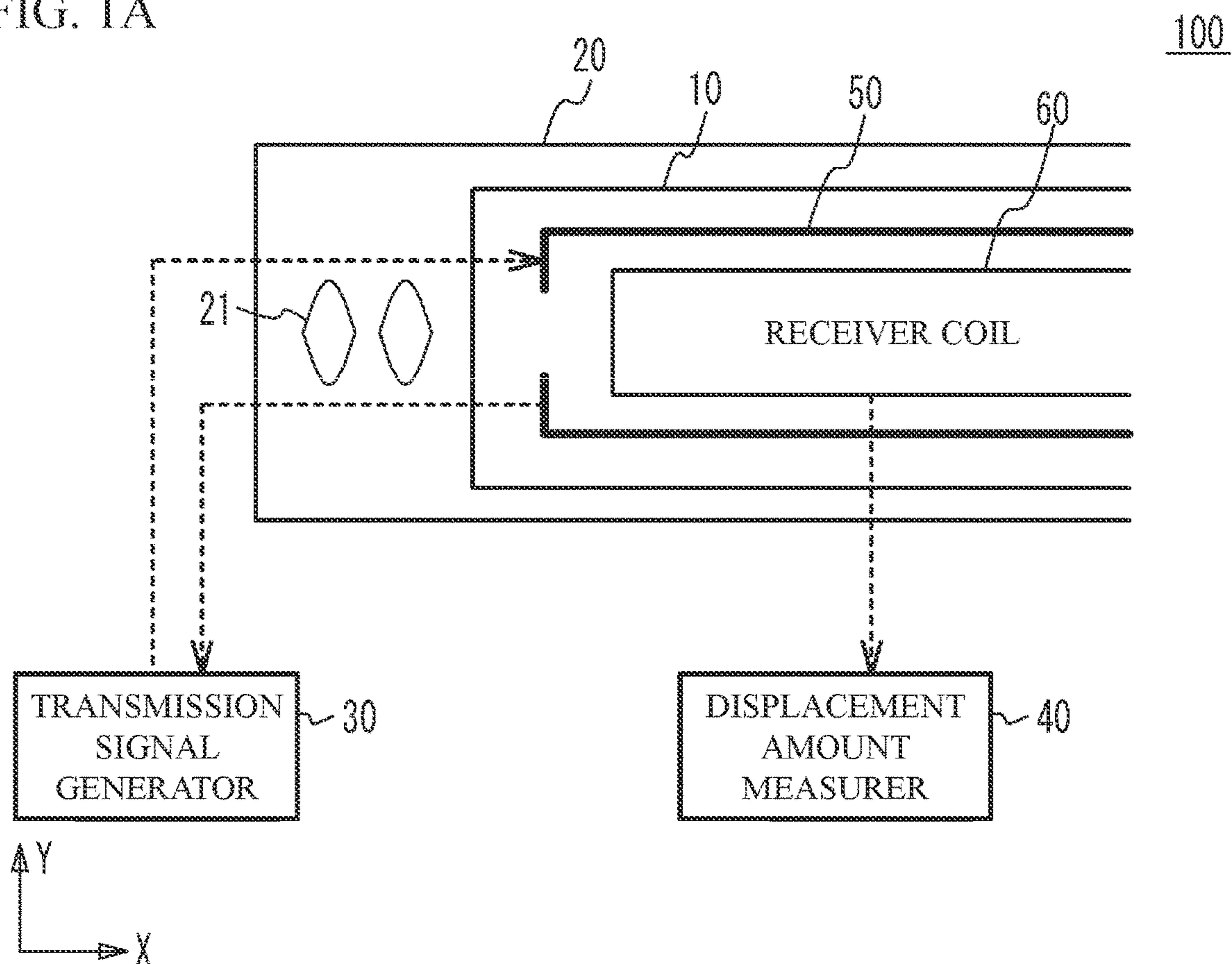


FIG. 1B

OUTPUT VOLTAGE

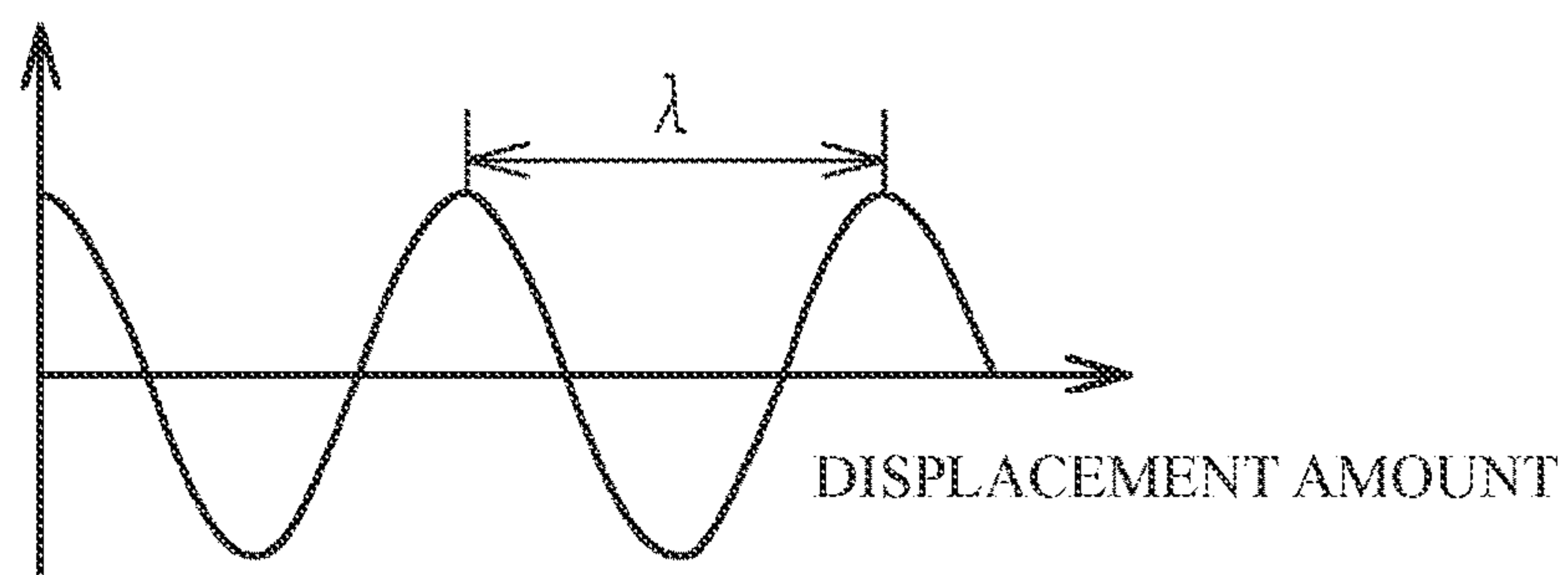


FIG. 2A

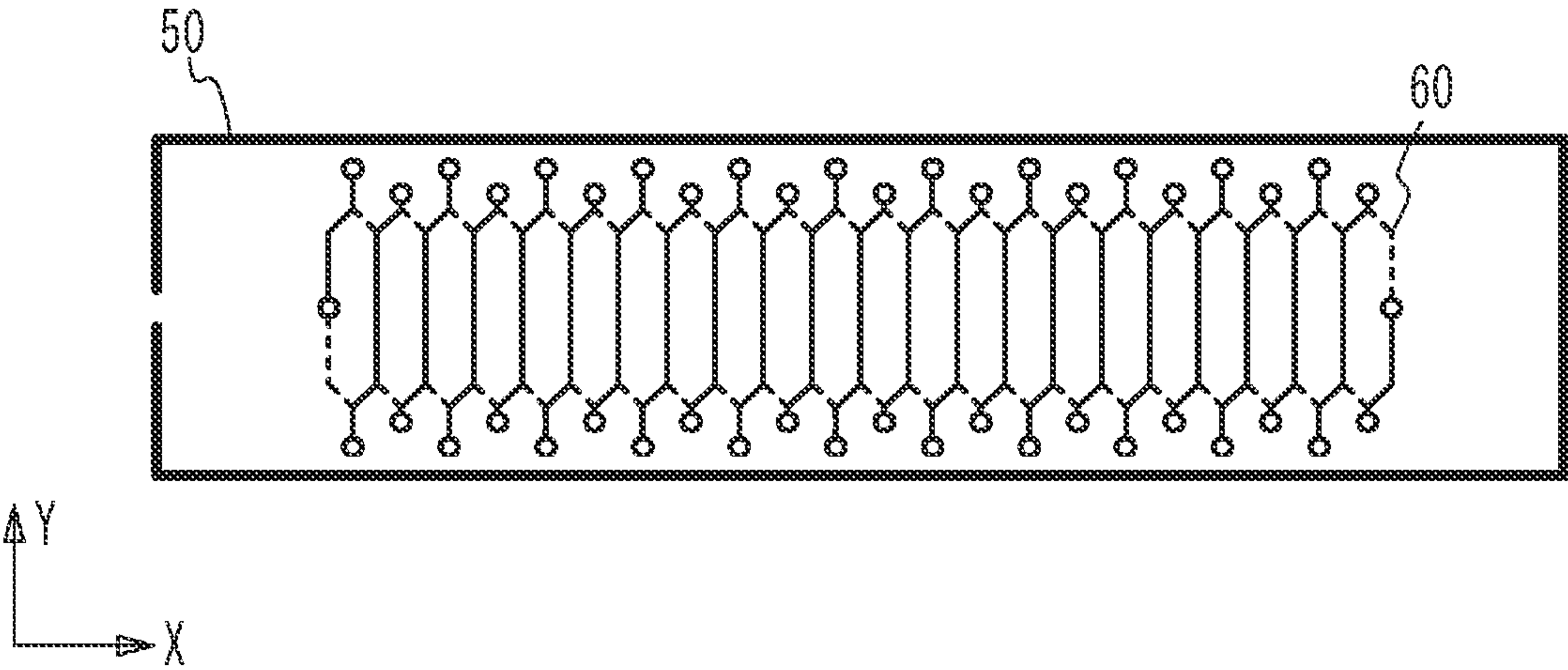


FIG. 2B

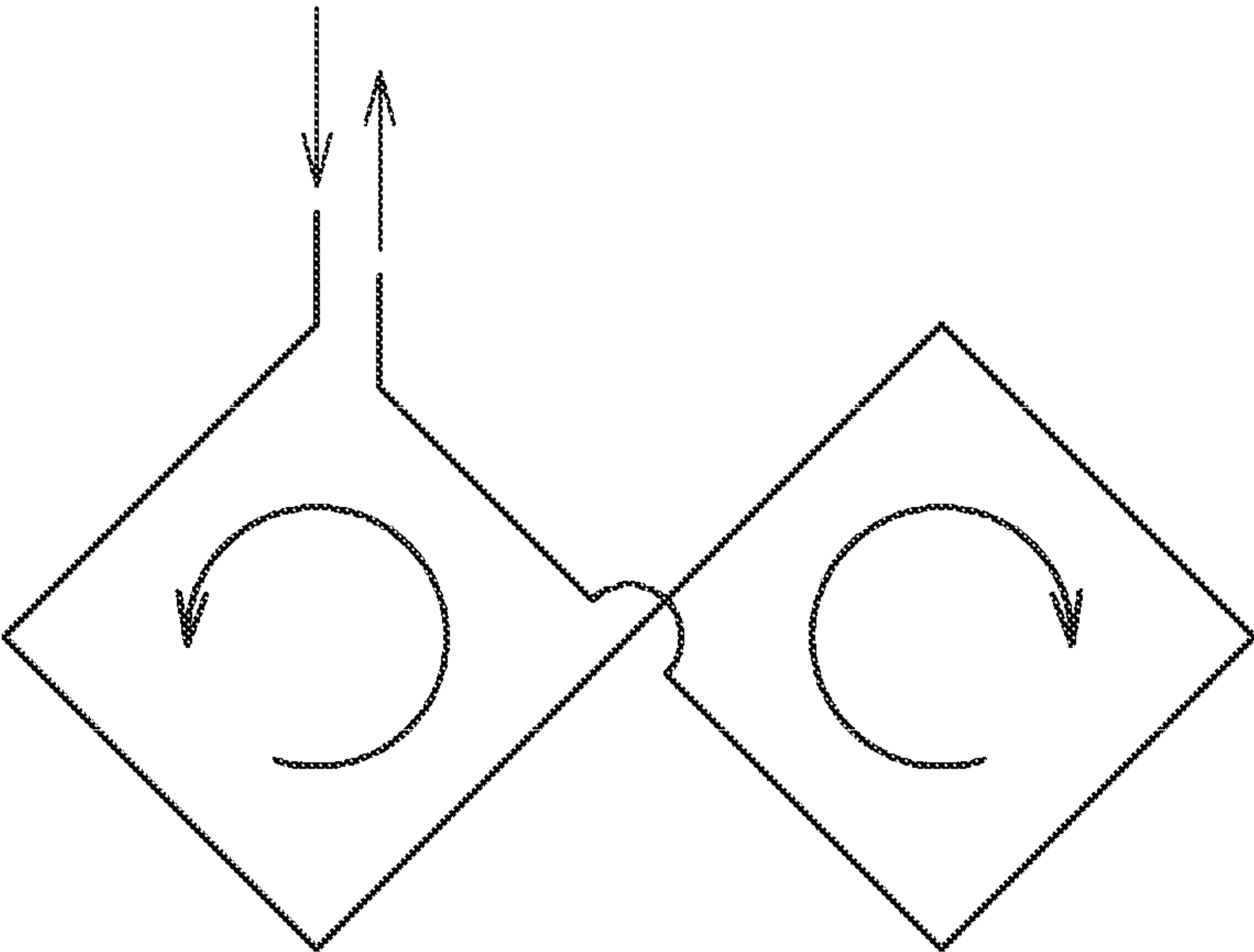


FIG. 2C

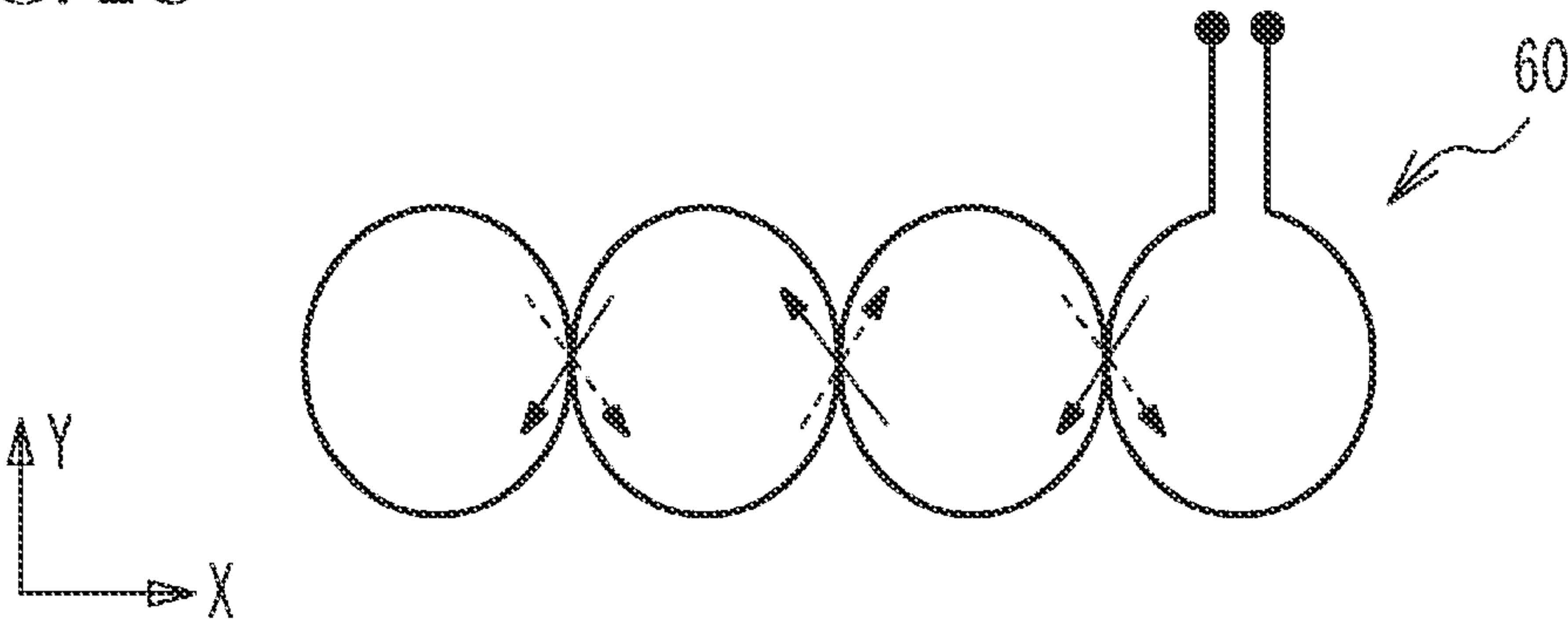


FIG. 3A

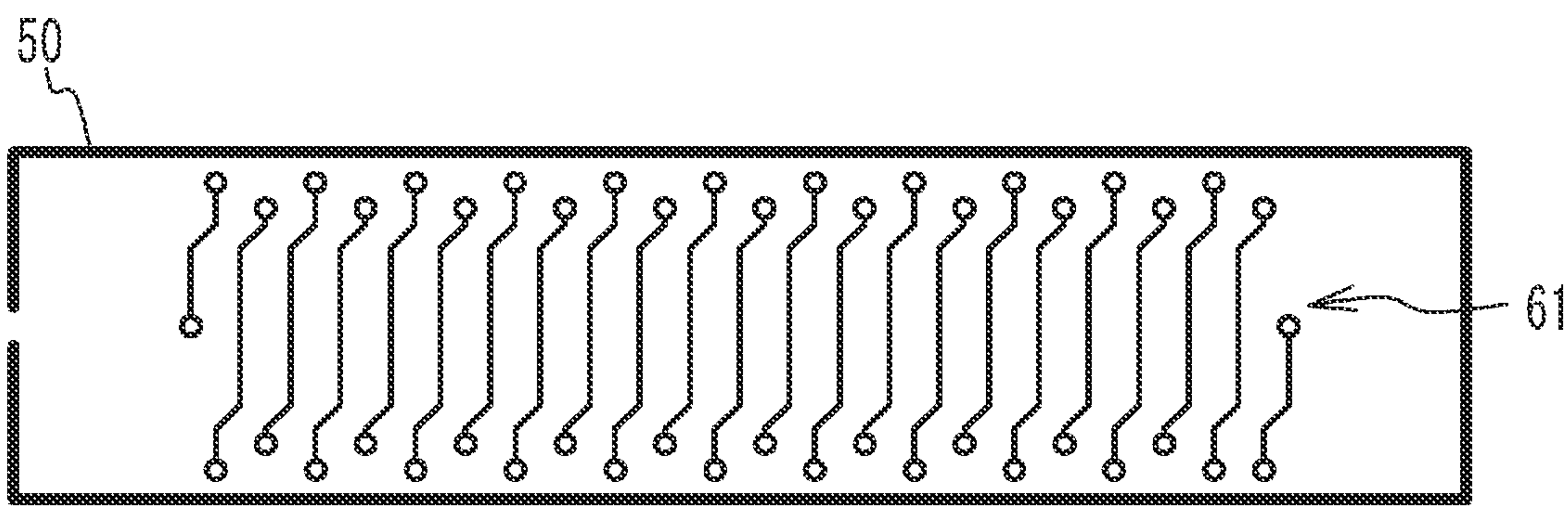


FIG. 3B

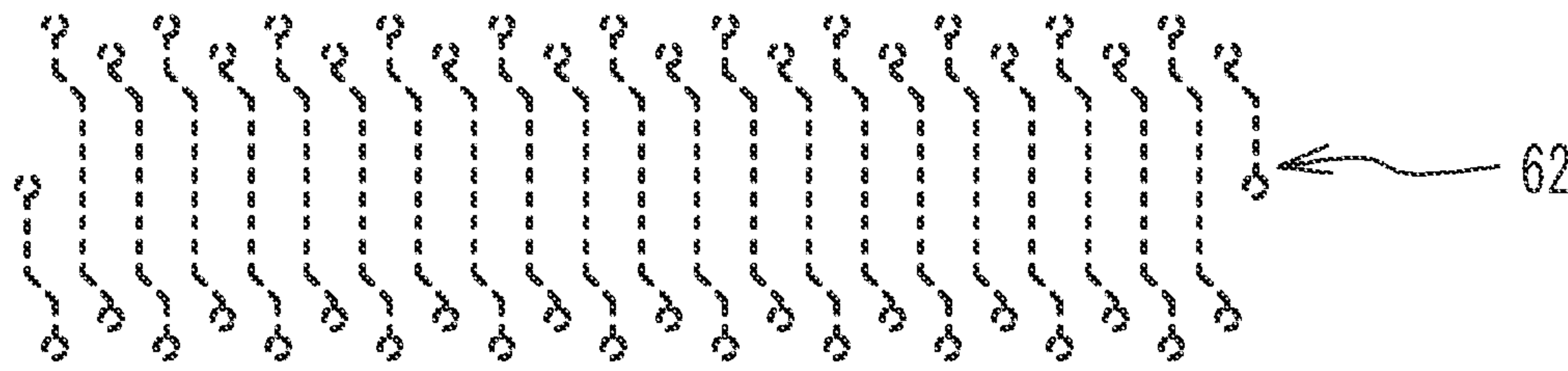


FIG. 4A

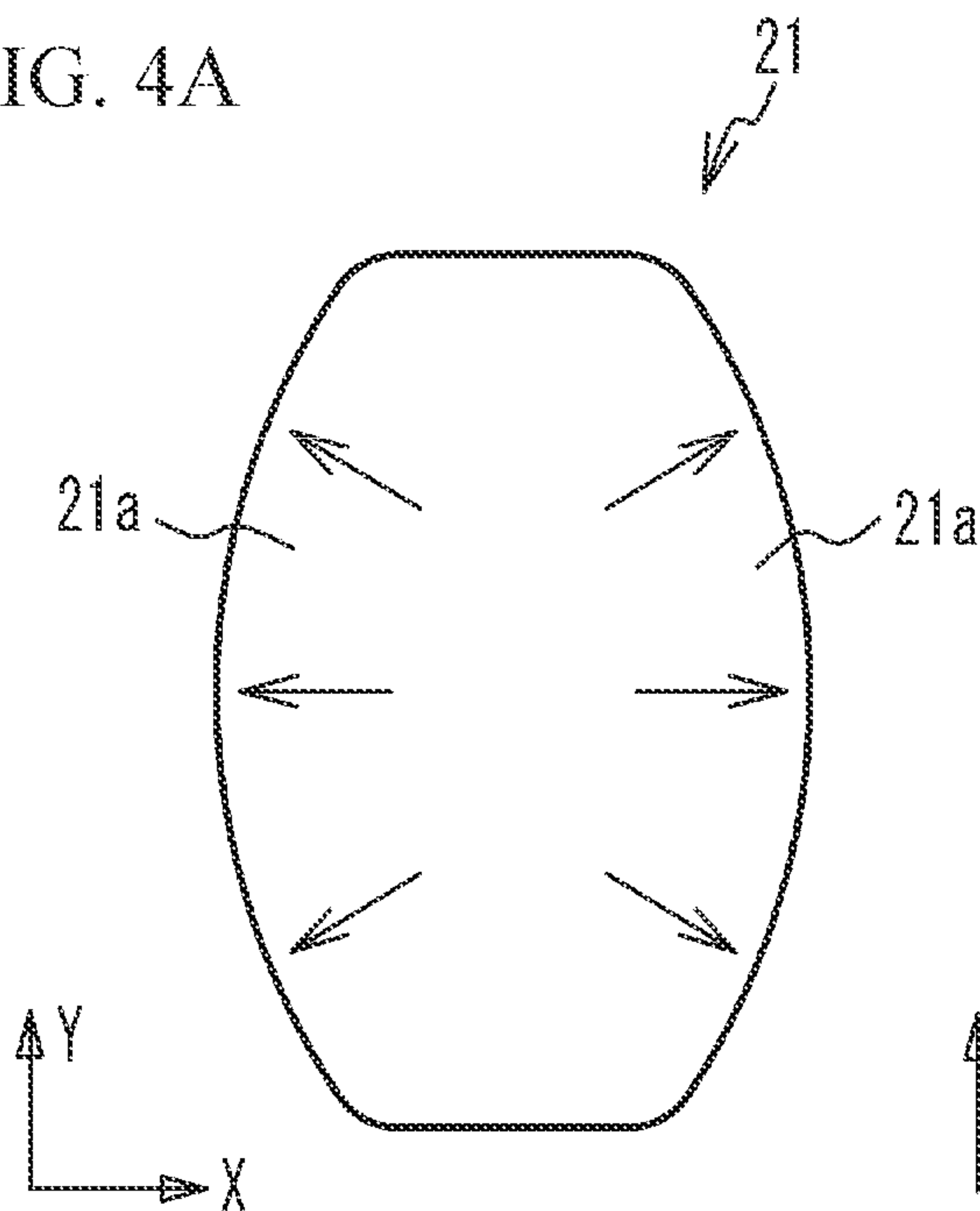


FIG. 4B

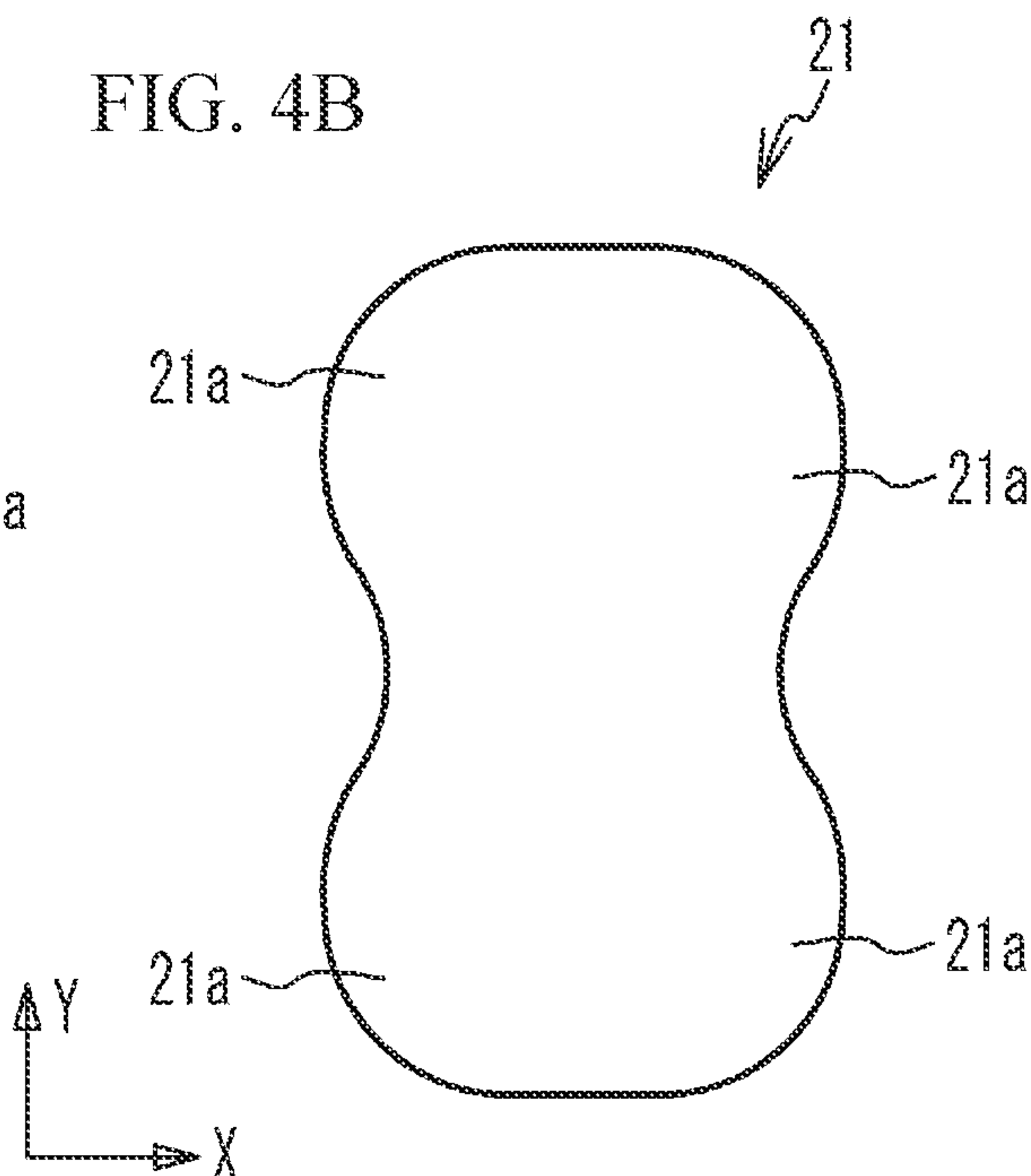


FIG. 4C

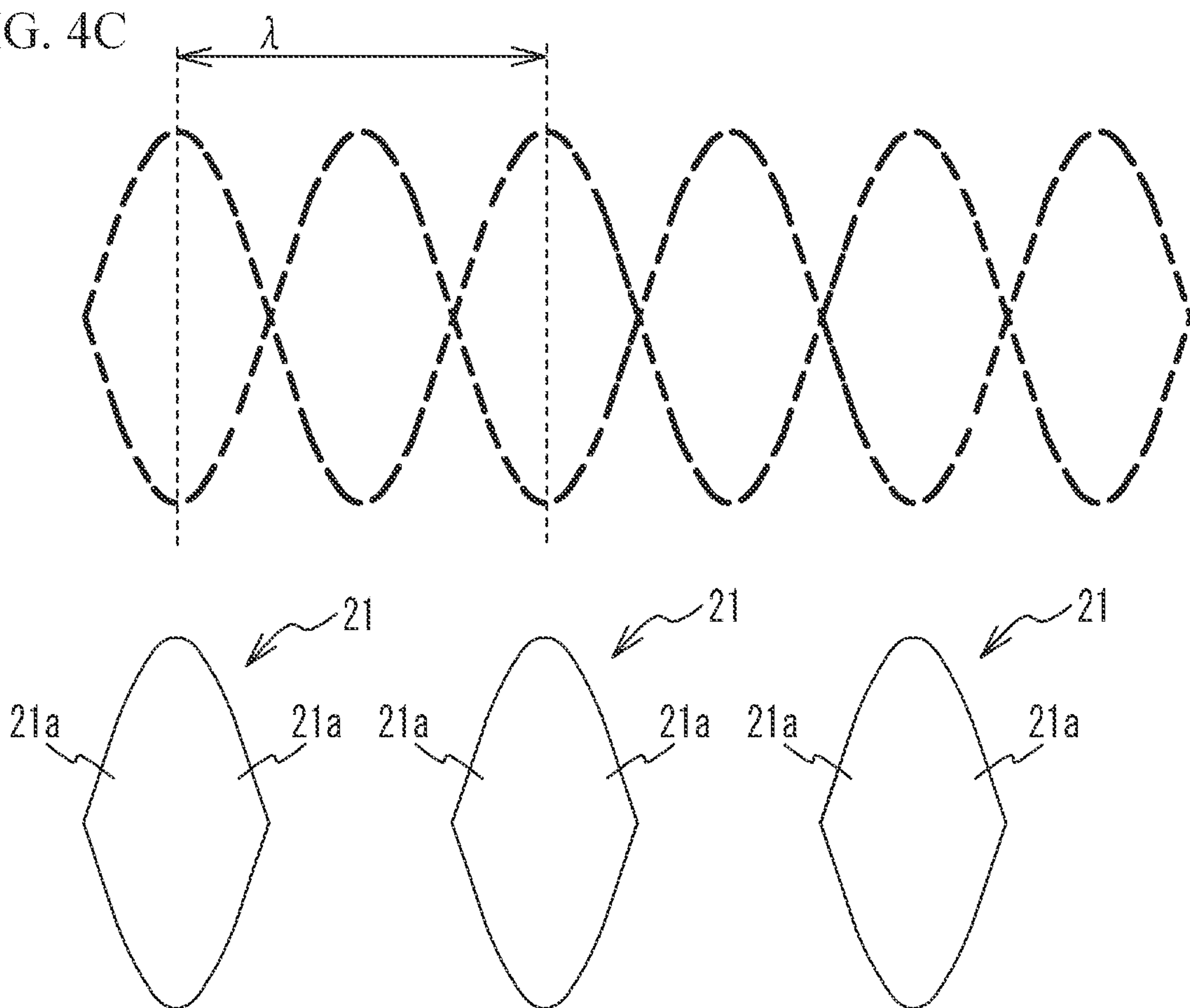


FIG. 5A

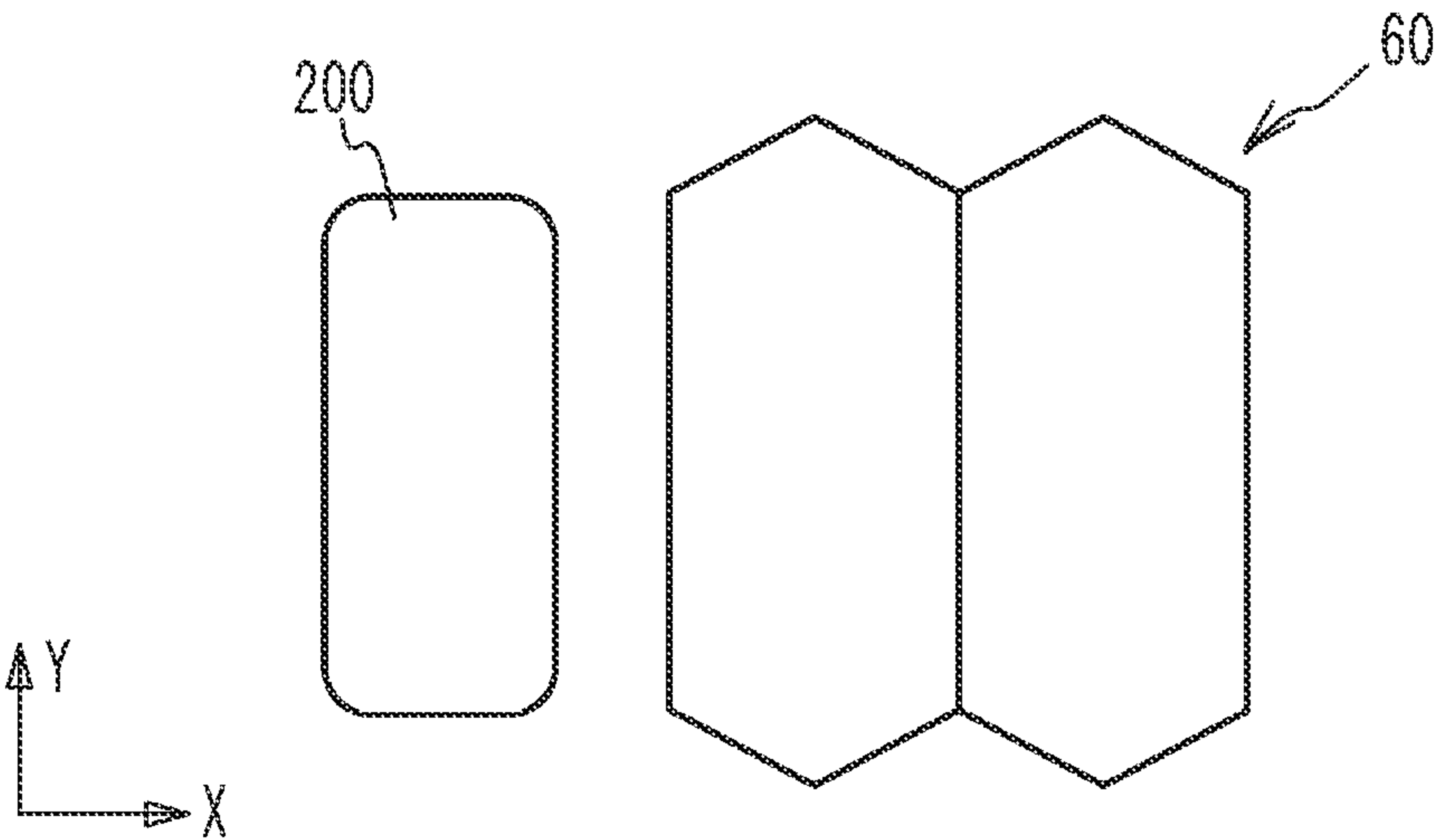


FIG. 5B

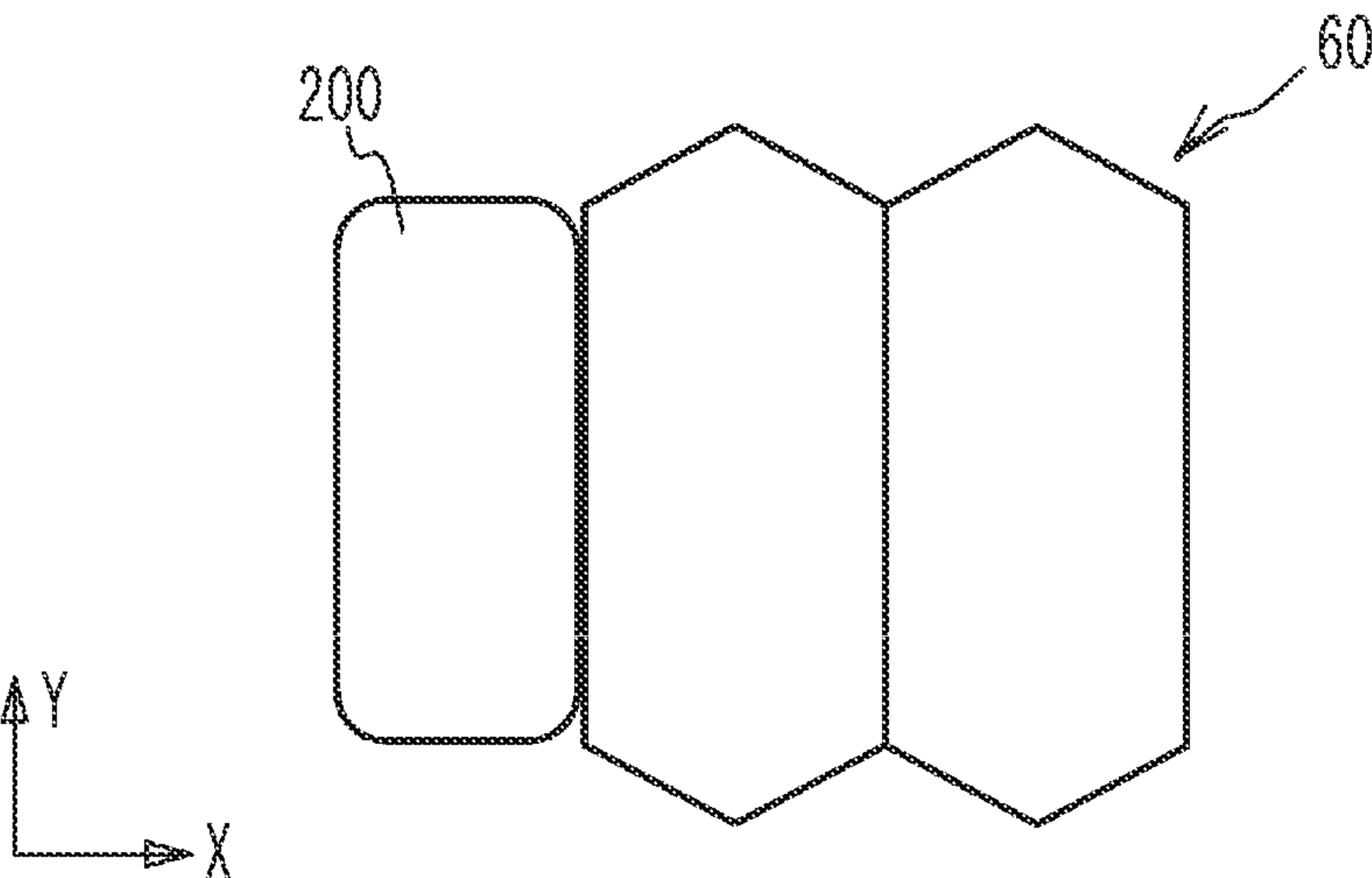


FIG. 5C

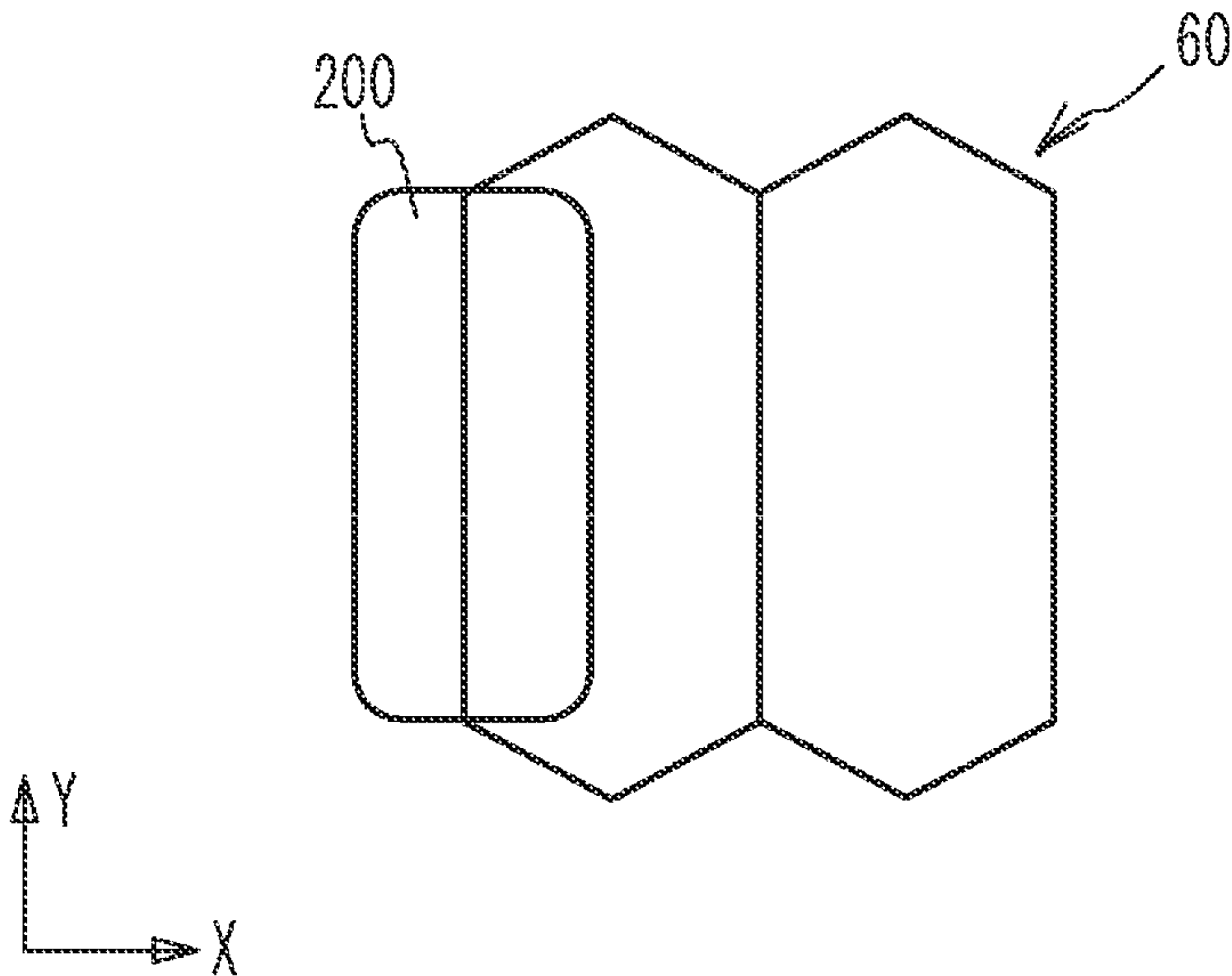


FIG. 6A

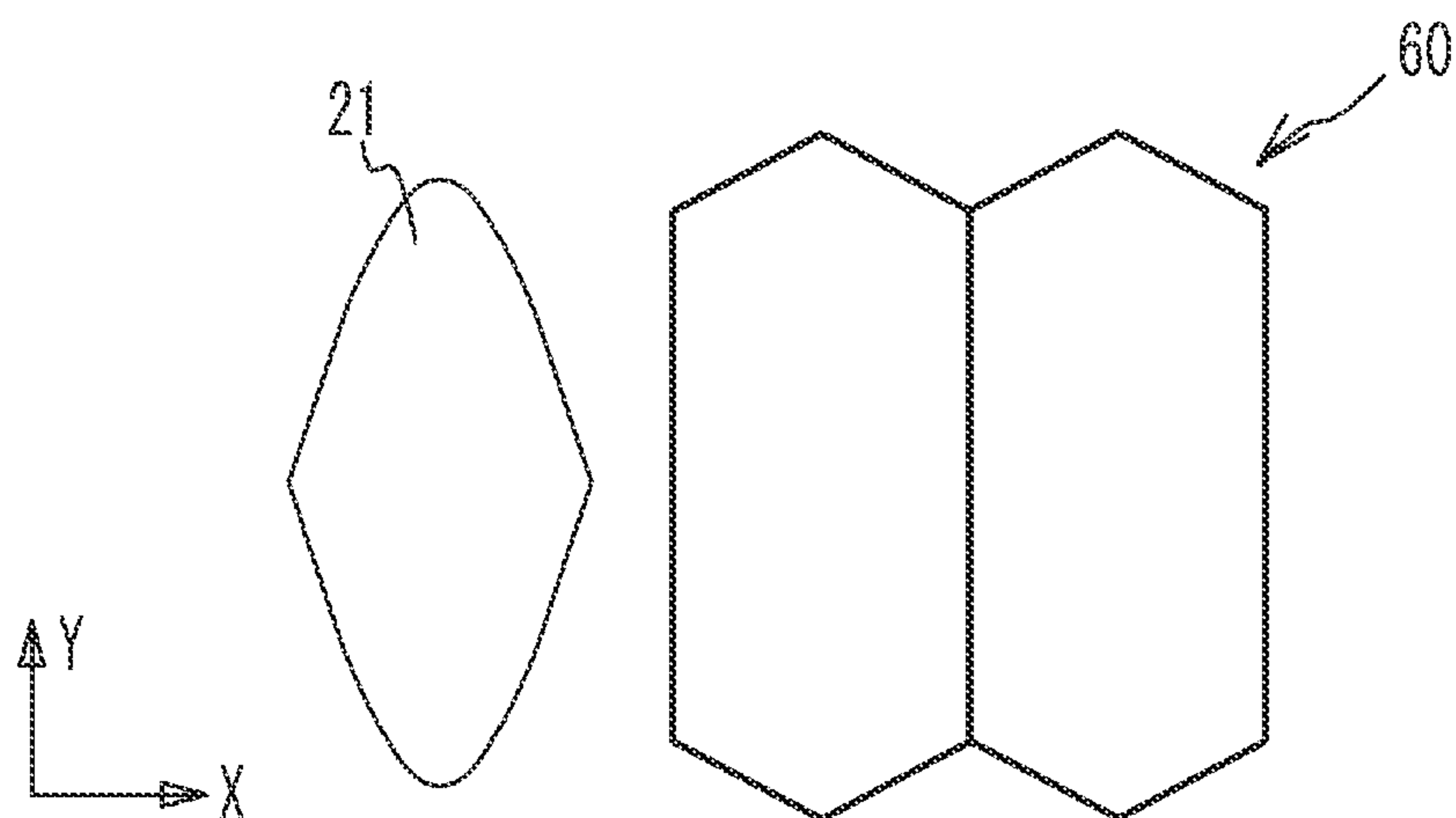


FIG. 6B

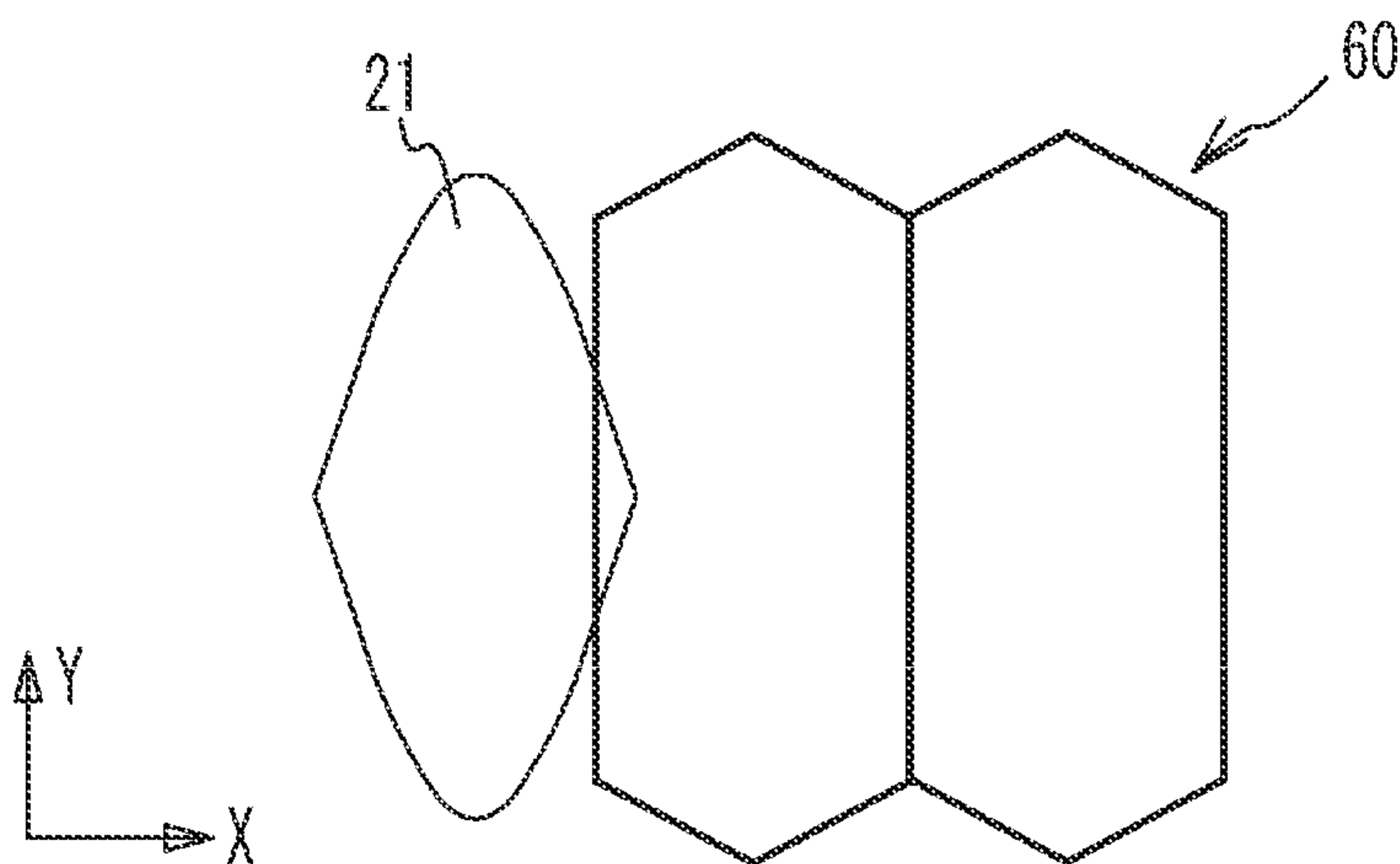
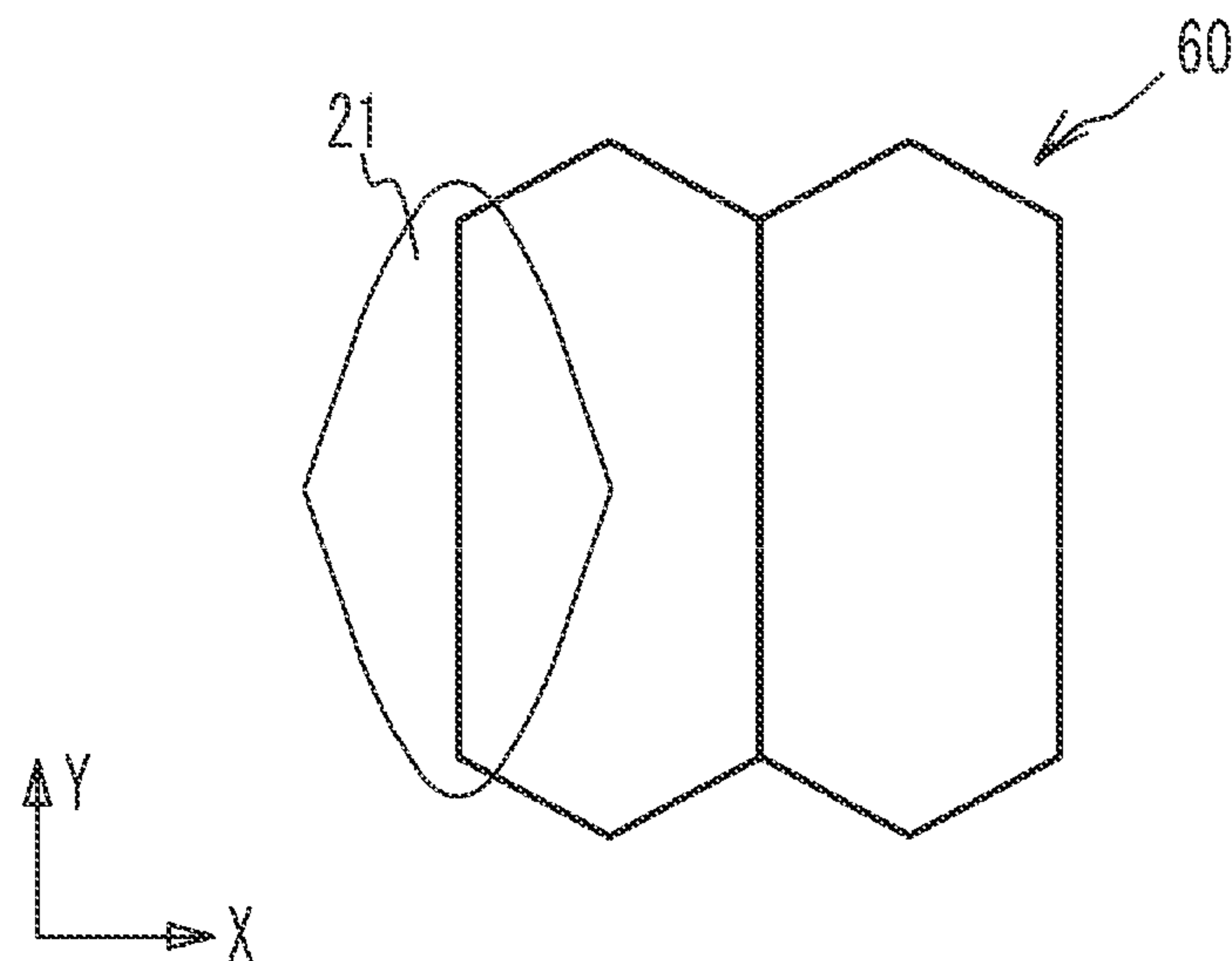


FIG. 6C



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SCALE AND ENCODER

CROSS-REFERENCE TO RELATED
APPLICATION

This application is based upon and claims the benefit of priority of the prior Japanese Patent Application No. 2019-227425, filed on Dec. 17, 2019, the entire contents of which are incorporated herein by reference.

FIELD

A certain aspect of embodiments described herein relates to a scale and an encoder.

BACKGROUND

There is known electromagnetic induction type encoders using electromagnetic connection between a detection head and a scale (for example, see Japanese Patent Application Publication No. 2009-168701).

SUMMARY

An unintended high frequency signal (higher harmonics wave) included in a sensor signal of the electromagnetic induction type encoder may cause degradation of measurement accuracy of the electromagnetic induction type encoder. Therefore, suppression of occurrence of the higher harmonics wave is requested. And so, it is thought that a receiver coil has a sine wave shape for the purpose of suppressing the occurrence of the higher harmonics wave. However, the receiver coil usually has a wiring pattern having two or more layers in a printed substrate. Therefore, there are many restrictions in designing of the receiver coil. It may be difficult to change the shape of the receiver coil, in a small size encoder having a micro sensor pattern.

In one aspect of the present invention, it is an object to provide a scale and an encoder that are capable of suppressing higher harmonics wave.

According to an aspect of the present invention, there is provided a scale including: a plurality of conductors that are arrayed in a given interval along a measurement axis, wherein each of the plurality of conductors has projection portions, each of which projects toward each side of the measurement axis, wherein at least a part of each of the projection portions has a curve projecting in the measurement axis.

According to another aspect of the present invention, there is provided an electromagnetic induction type encoder including: the above-mentioned scale; and a detection head that relatively moves in the measurement axis with respect to the scale, wherein the detection head has a transceiver coil configured to generate magnetic flux, wherein the plurality of conductors of the scale are configured to be electromagnetically coupled with the magnetic flux generated by the transceiver coil and generate magnetic flux that fluctuates in a predetermined spatial period in the measurement axis direction, wherein the detection head has a receiver coil is configured to be electromagnetically coupled with the magnetic flux generated by the plurality of conductors and detect a phase of the magnetic flux.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1A illustrates a structure of an electromagnetic induction type encoder;

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FIG. 1B illustrates a signal which is output by a receiver coil;

FIG. 2A illustrates a receiver coil;

FIG. 2B illustrates a flow of a current of a receiver coil;

FIG. 2C illustrates a receiver coil;

FIG. 3A illustrates a first wiring pattern formed in an upper layer of a printed substrate;

FIG. 3B illustrates a second wiring pattern formed in a lower layer of a printed substrate;

FIG. 4A to FIG. 4C illustrate details of a shape of a connection conductor;

FIG. 5A to FIG. 5C illustrate a connection conductor of a comparative embodiment; and

FIG. 6A to FIG. 6C illustrate a relationship between a connection conductor and a receiver coil.

DESCRIPTION OF EMBODIMENTS

The following is a description of embodiments, with reference to the accompanying drawings.

FIG. 1A illustrates a structure of an electromagnetic induction type encoder **100** using electromagnetic connection between a detection head and a scale. As illustrated in FIG. 1A, the electromagnetic induction type encoder **100** has a detection head **10** and a scale **20**. The detection head **10** relatively moves in a measurement axis direction with respect to the scale **20**. The detection head **10** and the scale **20** have a flat plate shape and face with each other through a predetermined gap. The electromagnetic induction type encoder **100** has a transmission signal generator **30** and a displacement amount measurer **40** and so on. In FIG. 1A, X-axis indicates a displacement direction of the detection head **10** (measurement axis). Y-axis is vertical to the X-axis in a plane formed by the scale **20**.

The detection head **10** has a transceiver coil **50**, a receiver coil **60** and so on. The transceiver coil **50** is a rectangular coil of which a longitudinal direction is the X-axis. As illustrated in FIG. 1A, the receiver coil **60** is inside of the transceiver coil **50**. The shape of the receiver coil **60** is described later.

In the scale **20**, a plurality of connection conductors **21** are arrayed in the fundamental period λ along the X-axis. The fundamental period is an interval between centers of the two connection conductors **21** next to each other, in the X-axis direction. Each of the connection conductors **21** is a closed loop coil or a board shape conductor without a hole. Each of the connection conductors **21** is electromagnetically coupled with the transceiver coil **50** and is also electromagnetically coupled with the receiver coil **60**.

The transmission signal generator **30** generates a transmission signal of a single phase AC and supplies the generated transmission signal to the transceiver coil **50**. In this case, magnetic flux is generated in the transceiver coil **50**. Thus, an electromotive current is generated in the plurality of connection conductors **21**. The plurality of connection conductors **21** are electromagnetically coupled with the magnetic flux generated by the transceiver coil **50** and generate magnetic flux fluctuating in the X-axis direction in a predetermined spatial period. The magnetic flux generated by the connection conductors **21** generates an electromotive current in the receiver coil **60**. The electromagnetic coupling among each coil fluctuates in accordance with the displacement amount of the detection head **10**. Thereby, a sine wave signal of the same period as the fundamental period λ is obtained. Therefore, the receiver coil **60** detects a phase of the magnetic flux generated by the plurality of connection conductors **21**. The displacement

amount measurer **40** can use the sine wave signal as a digital amount of a minimum resolution by electrically interpolating the sine wave signal. Thereby, the displacement amount measurer **40** measures the displacement amount of the detection head **10**. In FIG. 1B, a horizontal axis indicates a displacement amount of the detection head **10**. A vertical axis indicates an output voltage of the receiver coil **60**.

FIG. 2A illustrates the receiver coil **60**. The receiver coil **60** is inside of the transceiver coil **50** having a rectangular coil shape. As illustrated in FIG. 2B, a flow of a current of the receiver coil **60** is a shape in which a letter "8" lies down. As illustrated in FIG. 2A, the receiver coil **60** has a shape in which two polygon coils (for example, a hexagonal shape) are adjacent to each other. That is, the receiver coil **60** has a structure in which a plurality of twist-pair structures are arrayed along the X-axis direction. In the twist-pair structure, two hexagonal coils, in which a current and another current rotated reversely are achieved, are adjacent to each other. For example, a coil in which a current rotates in a clockwise direction and another coil in which a current rotates in a counter-clockwise direction are adjacent to each other. When the receiver coil **60** has the twist-pair structure, influence of disturbance is suppressed. The polygon shape of the receiver coil **60** has two sides in parallel with the Y-axis direction.

The shape of the coils in the receiver coil **60** is not limited to the polygon shape. For example, as illustrated in FIG. 2C, the coils of the receiver coil **60** may have a circle shape. The receiver coil **60** may not necessarily have only one twist structure. As illustrated in FIG. 2C, the receiver coil **60** may have a structure in which a wiring extends along a sine wave in the X-axis direction, returns at an end, and extends along another sinewave in the reverse X-axis direction.

In the twist-pair structure, the wiring intersects at a connection position of two coils. Therefore, the twist-pair structure has a two-layer structure. FIG. 3A illustrates a first wiring pattern **61** formed on an upper layer of a printed substrate. FIG. 3B illustrates a second wiring pattern **62** formed on a lower layer of the printed substrate. The upper layer is bonded to the lower layer. Terminals of the first wiring pattern **61** and terminals of the second wiring pattern **62** are connected via through-hole wirings or the like. Thus, the receiver coil **60** is structured.

The sine wave signal detected by the receiver coil **60** may include a signal having an unintended frequency (higher harmonics wave). The higher harmonics wave may cause degradation of the measurement accuracy of the electromagnetic induction type encoder **100**. Therefore, suppression of the occurrence of the higher harmonics wave is requested. And so, it is thought that the receiver coil **60** has the sine wave shape. However, the receiver coil **60** usually has a wiring pattern having two or more layers in the printed substrate, as illustrated in FIG. 3A and FIG. 3B. Therefore, there are many restrictions in the designing of the receiver coil **60**. It may be difficult to change the shape of the receiver coil **60** to the sine wave shape, in a small size encoder having a micro sensor pattern. And so, the electromagnetic induction type encoder **100** of the embodiment has a structure for suppressing the occurrence of the higher harmonics wave even if the electromagnetic induction type encoder **100** is downsized.

FIG. 4A illustrates details of the shape of the connection conductor **21**. As illustrated in FIG. 4A, the connection conductor **21** has projection portions **21a** which projects toward both sides in the X-axis direction. In FIG. 4A, the projection portions **21a** are formed in center positions of the connection conductor **21** in the Y-axis direction and project

toward the both sides in the X-axis direction. At least a part of the projection portion **21a** has an outer edge having a curvature which projects in the X-axis direction and is curved. And, as indicated with arrows, the projection portion **21a** projects and is curved.

On the both sides in the measurement axis, the number of the projection portions **21a** is not limited. For example, as illustrated in FIG. 4B, each of the connection conductors **21** has two or more projection portions **21a** in the Y-axis direction.

As illustrated in FIG. 4C, it is preferable that the shape of the outer edge of each of the connection conductors **21** coincides with a sine wave or is similar to the sine wave. In an upper figure of FIG. 4C, a sine wave having a period λ and another sine wave which is flipped upside down are illustrated. In lower figure of FIG. 4C, two or more of the connection conductors **21** arrayed with the period λ are illustrated. The connection conductors **21** have a shape in which periodical shapes of the upper figure are alternately extracted. As illustrated in the lower figure of FIG. 4C, the projection portion **21a** of the connection conductor **21** may have a sharp portion which is not curved.

FIG. 5A to FIG. 5C illustrate a connection conductor **200** of a comparative embodiment. As illustrated in FIG. 5A, the connection conductor **200** has a rectangular shape having sides in parallel with the X-axis direction and sides in parallel with the Y-axis direction. FIG. 5B illustrates a case where the connection conductor **200** gets close to the receiver coil **60** in the X-axis direction. When the receiver coil **60** overlaps with the connection conductor **200** as illustrated in FIG. 5C, large signal intensity is achieved. In this manner, when the receiver coil **60** starts to overlap with the connection conductor **200**, signal intensity is rapidly enlarged. On the other hand, when the overlapping of the receiver coil **60** with the connection conductor **200** finishes, the signal intensity is rapidly lowered. There is an error in the detected signal, when there is variation in the width of the connection conductor **200** in the X-axis direction because of manufacturing error or the like or there is variation in the position of the connection conductor **200** in the X-axis direction because of manufacturing error or the like. Therefore, a higher harmonics wave may occur.

FIG. 6A illustrates a case where the receiver coil **60** does not overlap with the connection conductor **21**. As illustrated in FIG. 6B and FIG. 6C, when the receiver coil **60** starts to overlap with the connection conductor **21**, the signal intensity gradually increases. When the overlapping amount of the receiver coil **60** with the connection conductor **21** gradually decreases, the signal intensity gradually decreases. In the structure, the error in the detected signal is suppressed, even if there is variation in the width of the connection conductor **21** in the X-axis direction because of manufacturing error or even if there is variation in the position of the connection conductor **200** in the X-axis direction because of the manufacturing error. Moreover, the shape of the outer edge of the connection conductor **21** is similar to the shape of the sine wave signal detected by the receiver coil **60**, because the tip of the projection portion **21a** in the measurement axis is curved. Therefore, the occurrence of the higher harmonics wave is suppressed. When the shape of the outer edge of the connection conductor **21** is similar to the sine wave as illustrated in FIG. 4C, the occurrence of the higher harmonics wave is suppressed.

In the embodiment, the connection conductor **21** has the projection portions **21a** which projects to the both sides in the X-axis direction. At least a part of the projection portion **21a** has the curvature forming a curve which projects in the

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X-axis direction. It is therefore possible to suppress the higher harmonics wave. The connection conductor **21** does not have the double-layer structure of the receiver coil **60**. Therefore, there is less restriction in designing of the connection conductor **21**. The embodiment can be applied to a small size encoder having a micro sensor pattern. Accordingly, the electromagnetic induction type encoder **100** of the embodiment can suppress the occurrence of the higher harmonics wave, even if the electromagnetic induction type encoder **100** is downsized.

The present invention is not limited to the specifically disclosed embodiments and variations but may include other embodiments and variations without departing from the scope of the present invention.

What is claimed is:

1. An electromagnetic induction type encoder comprising:
a scale having a plurality of conductors that are arrayed in a given interval along a measurement axis, wherein each of the plurality of conductors has projection portions, each of which projects toward each side of the measurement axis, wherein at least a part of each of the projection portions has a curve projecting in the measurement axis direction, wherein an end point of each of the projection portions angularly projects in the measurement axis direction, wherein the plurality of conductors are spaced from each other and are not connected to each other, in a region where the plurality of conductors are arrayed in the given interval; and
a detection head that relatively moves in the measurement axis with respect to the scale,
wherein the detection head has a transceiver coil configured to generate a first magnetic flux,
wherein the plurality of conductors of the scale are configured to be electromagnetically coupled with the first magnetic flux generated by the transceiver coil and generate a second magnetic flux that fluctuates in a predetermined spatial period in the measurement axis direction,
wherein the detection head has a receiver coil configured to be electromagnetically coupled with the second

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magnetic flux generated by the plurality of conductors and detect a phase of the second magnetic flux,
wherein the receiver coil has periodical elements, each of which has a side at an end of the measurement axis, the side extending along a direction orthogonal to the measurement axis on a face of the detection head facing the scale, and

wherein the receiver coil has a polygon shape having two sides that are vertical to the measurement axis.

2. The electromagnetic induction type encoder of claim 1, wherein the plurality of conductors are closed loop coils or board shape conductors without a hole.

3. The electromagnetic induction type encoder of claim 1, wherein an outer edge shape of the plurality of conductors has a sine wave shape.

4. The electromagnetic induction type encoder of claim 1, wherein the plurality of conductors are board shape conductors without a hole.

5. The electromagnetic induction type encoder of claim 1, wherein the plurality of conductors are electrically coupled with neither the transceiver coil nor the receiver coil.

6. The electromagnetic induction type encoder of claim 1, wherein the plurality of conductors are not overlapped each other.

7. The electromagnetic induction type encoder of claim 1, wherein the projection portions are formed in a center position of each of the plurality of conductors in a direction vertical to the measurement axis.

8. The electromagnetic induction type encoder of claim 1, wherein each of the plurality of conductors has two sides in a direction of the measurement axis, and each one of the two sides has two or more of the projection portions in a direction vertical to the measurement axis.

9. The electromagnetic induction type encoder of claim 1, wherein the projection portions are formed in a center position of each of the plurality of conductors in a first direction vertical to the measurement axis, and the plurality of conductors are not overlapped each other in a second direction vertical to the first direction and the measurement axis.

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